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THEORIES OF LIGHT[1]

By Professor H. M. MACDONALD

UNIVERSITY OF ABERDEEN

EARLY speculations as to how impressions were produced on the senses ascribed the sensations associated with the senses of taste and smell to the emanation of small particles of the substances involved, and ascribed the sensations associated with the sense of sound to undulations or pulses in the air. The sensations associated with the sense of sight were assumed by some philosophers to be produced in a manner similar to those belonging to the senses of taste and smell, while by others they were assumed to be produced in a manner similar to those of sound. In the first case they were assumed to be produced by emanations from the body seen, in the second case by undulations due to the body. Among the Greeks Empedocles was an exponent of the first view, while Aristotle supported the second view. It should be noted that different views were held by those who supported an emanation theory as to the nature of the emanation. Some held that the emanation consisted of small particles of matter, while others held that the emanation was something different from matter.

In the fifteenth and sixteenth centuries, when attention was being directed again to the study of natural phenomena, the two types of theory were revived. The form of the emanation theory which was adopted ultimately is that due to Newton, usually referred to as the corpuscular theory of light. In this theory light is regarded as consisting of very small particles of matter emitted by luminous bodies with the same velocity, the velocity of light. These light particles are supposed to be repelled or attracted by the molecules of material bodies according to some law de-

[1] Address of the president of Section A—Mathematical and Physical Sciences—British Association for the Advancement of Science, Aberdeen, September, 1934.

pending on the distance between them. It is further assumed that the law is such that the force can change from an attraction to a repulsion or from a repulsion to an attraction, that these forces are insensible at sensible distances, that the motion of a light particle satisfies the ordinary laws of dynamics, and that, as the light particle moves, it passes through states which have been termed "fits of easy transmission and easy reflection" by Newton, these states recurring periodically.

The form of the undulating theory which was adopted is due to Huygens. On this theory light consists of undulations propagated through an elastic medium which fills all space; it is assumed that the elasticity of this medium is different in different material bodies and different from its elasticity in free space, and that therefore the velocity of propagation of light in a material medium is different from its velocity of propagation in free space. It is a consequence of either theory that when all the media are isotropic $\Sigma\mu s$ along the path of a ray from one point to another point is stationary, and this relation is sufficient to give the results which are classed under the term of geometrical optics. The modification necessary in this result to make it applicable to the case of crystalline media was effected by Laplace, who made use of the corpuscular theory of light in his investigation and assumed that the velocity of the light particles in a crystalline medium depended on the direction. The same result was also derived from the undulatory theory.

At the end of the eighteenth century the corpuscular theory of light was the theory which was accepted generally; one of the main arguments against an undulatory theory was its failure to explain the formation of shadows. Early last century the principle of interference was put forward by Young to account for the formation of shadows on the undulatory theory, and somewhat later, though independently, Fresnel arrived at the same result. In 1816 Arago and Fresnel showed that light polarized in perpendicular planes did not interfere. It is not improbable that Fresnel had inferred already that the direction of the disturbance which constituted light was transverse to the direction of propagation, and that these experiments confirmed it, but he makes no reference to the principle of transversality in his writings for a considerable time. The earliest explicit reference to the principle I have been able to find is contained in a letter from Young to Arago written in January, 1817. Young had visited Arago after the experiments had been carried out in 1816 and discussed them with him, and he appears to have been the only one who saw the importance of Fresnel's inference and who agreed with it. In his essay on diffraction (1818) Fresnel does not refer to the principle; he uses Huygens' principle and the principle of interference to obtain his results, principles which are independent of the direction of the disturbance. After the publication of his essay on diffraction, Fresnel applied his law of transversality to the phenomena of polarization, the propagation of light in crystalline media and other problems. He obtained and verified by observation relations between the intensities of the incident, transmitted and reflected light, when light is incident on a surface which separates two isotropic transparent media, and these relations have ever since been regarded as conditions which any adequate theory of light must satisfy. This is also true of the results he obtained for the propagation of light in crystalline media. Fresnel's method of attack is to a great extent geometrical and independent of any hypothesis as to the nature of a medium.

The developments which had taken place in analytical mathematical methods beginning with the work of the Bernoullis on strings which led to Fourier's work and Lagrange's treatment of dynamical problems made it possible to submit the hypothesis that light is due to the vibrations of an elastic medium to a more rigorous analysis. The earliest investigation of this kind is due to Cauchy. In Cauchy's treatment the elastic medium is supposed to consist of small particles or molecules which act on each other, and the further hypothesis is made that the force between any two particles is along the line joining the two points which are taken to represent the two particles. As the same problem was discussed by Green in a more general way in 1837 it is unnecessary to refer to Cauchy's results in detail.

The hypothesis which Green made with respect to the mutual actions of portions of the elastic medium was that they possessed a work function. He investigated the form of this function and proved that when the medium is isotropic and homogeneous it involves two constants, and that, if transverse waves are propagated in the medium independently of normal waves, the velocity of propagation of normal waves must be either indefinitely great or indefinitely small. He further proved that if the elastic medium is stable the velocity of propagation of normal waves in it must be indefinitely great.

The difference between two isotropic homogeneous media is assumed to be a difference between their densities,[2] and on this assumption the relations between the amplitudes of the incident, the transmitted and the reflected waves are obtained when waves are incident on a surface separating two such media. For

[2] The assumption that the difference between two isotropic homogeneous media is a difference in the elastic constants leads to results which do not agree with the observed facts.

waves polarized in the plane of incidence the relations are the same as Fresnel's, and for waves polarized perpendicularly to the plane of incidence the relations are very approximately the same as Fresnel's, except when the index of refraction is great. The difference between Cauchy's hypothesis as to the nature of the mutual actions of the medium and Green's hypothesis has been referred to above; another important difference in their treatments is that Cauchy assumes that the direction of the disturbance in the medium is parallel to the plane of polarization, while Green, in accordance with Fresnel's view, assumes that this direction is perpendicular to the plane of polarization.

Green's investigation is of special interest, as it is the first where Lagrange's dynamical method is used for the treatment of a physical problem, and where the advantages of using a general dynamical principle as the basis of the argument rather than hypotheses which involve the assumption of particular modes of action is recognized.

In 1839 Green applied the same method of treatment to the investigation of the propagation of waves of light in a crystalline medium. In addition to the limitation used in his previous investigations, that transverse waves can be propagated in the medium independently of normal waves, he introduces the further limitation in accordance with Fresnel's theory that the media satisfy the condition that the directions of the transverse vibrations are always in the front of the wave. With these limitations he proves that, if the direction of a disturbance is parallel to the plane of polarization and the medium is free from the action of any external forces, the directions of polarization and the velocities of propagation are the same as in Fresnel's theory. In his previous investigations he had proved that in order to satisfy Fresnel's relations between the amplitudes of the incident, transmitted and reflected waves at the surface separating two isotropic homogeneous media, the direction of a disturbance is perpendicular to the plane of polarization. He then shows that in order to satisfy Fresnel's results for crystalline media when the direction of a disturbance is perpendicular to the plane of polarization it is necessary to assume the existence of extraneous forces, and that, with the appropriate restrictions on these extraneous forces, the results agree with those of Fresnel's theory.

It thus appears that an elastic solid medium which is self-contained and free from external constraints will not account for the observed facts. Cauchy arrived at the same result almost simultaneously.

Various modifications of Green's elastic solid theory of light have been proposed, but none of them is satisfactory. Perhaps the most interesting is that proposed by Lord Kelvin in his Baltimore Lectures. This theory assumes that normal waves in the elastic medium are propagated with zero velocity, and to get over the difficulty, pointed out by Green, that such a medium is not stable, the medium is supposed to be attached to a boundary. Thus, although this theory gives results for the relations between the amplitudes of the incident, the transmitted and the reflected waves at the boundary separating two isotropic media and also for the propagation of waves in crystalline media which agree with Fresnel's results, it is open to the same objection as Green's elastic solid theory which requires the intervention of extraneous forces, as the condition that the medium is attached to a boundary postulates the existence of some other medium which acts on and controls it.

Although these different investigations did not succeed in establishing a satisfactory mechanical theory of light, they were instrumental in advancing the knowledge of the subject. One important result emerged, that any theory to be satisfactory must agree with Fresnel's results, and some writers, *e.g.*, Lorenz, based many of their investigations on Fresnel's results.

In Green's treatment of the elastic solid theory the Lagrangian function used by him is of the type which is expressed as the difference of a kinetic energy function and a potential energy function. The kinetic energy function is the sum of the squares of the velocities of the medium multiplied by the density, and, if the rate of transfer of energy due to a source in such a medium emitting waves of one frequency is evaluated, it will be found that it is oscillatory, and this is also true when the potential energy function is of the most general type for an elastic medium. It should be observed that, just as in the case of waves of sound from a source or of waves in water, there is an actual displacement of the medium itself, *e.g.*, in the case of waves of sound air must be supposed to be pumped in and out at the source, and this accounts for the fact that the rate of transfer of energy is oscillatory. This suggsts that it should be possible to pump out portions of such a medium, and raises the question whether a medium which is subject to the laws of dynamics and which possesses a kinetic energy of this type can be an ultimate medium which will account for the phenomena of light.

The next important stage in the development of theories of light is the discovery by Faraday in 1845 that when polarized light passed through a transparent medium its plane of polarization was rotated by the imposition of a magnetic field. In the introduction to his account of these experiments Faraday says:

I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which

the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalents of power in their action. This strong persuasion extended to the powers of light, and led, on a former occasion, to many exertions, having for their object the discovery of the direct relation of light and electricity, and their mutual action in bodies subject jointly to their power; but the results were negative. These ineffectual exertions, and many others which were never published, could not remove my strong persuasion derived from philosophical considerations; and, therefore, I recently resumed the inquiry by experiment in a most strict and searching manner, and have at last succeeded in *magnetizing and electrifying a ray of light.*

In a footnote added subsequently Faraday says:

Neither accepting nor rejecting the hypothesis of an aether, or the corpuscular, or any other view that may be entertained of the nature of light; and, as far as I can see, nothing being really known of a ray of light more than of a line of magnetic or electric force, or even of a line of gravitating force, except as it and they are manifest in and by substances; I believe that, in the experiments I describe in the paper, light has been magnetically affected.

Almost twenty years later, in 1865, Maxwell propounded a theory of light in his memoir, "A Dynamical Theory of the Electromagnetic Field."[3] In the introduction Maxwell states:

We have therefore some reason to believe, from the phenomena of light and heat, that there is an aethereal medium filling space and permeating bodies, capable of being set in motion and of transmitting that motion from one part to another and of communicating that motion to gross matter so as to heat it and affect it in various ways.

We may therefore receive, as a datum derived from a branch of science independent of that with which we have to deal, the existence of a pervading medium, of small but real density, capable of being set in motion and of transmitting motion from one part to another with great, but not infinite velocity.

Hence the parts of this medium must be so connected that the motion of one part depends in some way on the motions of the rest; and at the same time these connections must be capable of a certain kind of elastic yielding, since the communication of motion is not instantaneous, but occupies time.

The medium is therefore capable of receiving and storing up two kinds of energy, the "actual" energy depending on the motions of its parts, and "potential" energy, consisting of the work which the medium will do in recovering from displacement in virtue of its elasticity.

[3] What might be termed an electric theory of light was propounded by Oersted; in this theory light was regarded as a succession of electric sparks.

Maxwell postulates further that the all-pervading medium possesses physical characteristics of the same kind as a homogeneous isotropic dielectric, that the effect of the action of an electric force on it is the production of what he terms "electric displacement," which is "a kind of elastic yielding to the action of the force similar to that which takes place in structures and machines owing to the want of perfect rigidity of the connections."

He shows that the application of the general equations of electrodynamics, derived from the Ampère-Faraday laws, to the case of a magnetic disturbance propagated through a non-conducting field gives the result that the only disturbances which can be so propagated are those which are transverse to the direction of propagation, and that the velocity of propagation is the velocity v, which expresses the number of electrostatic units of electricity which are contained in one electromagnetic unit.

The all-pervading medium which Maxwell postulates is a medium which possesses to some extent the physical characteristics of an elastic solid, and it is probable that his replacement of the expression for the electrokinetic energy which is obtained from Faraday's laws by an expression which gives the energy in terms of the magnetic force, was effected to make it similar to the expression for the kinetic energy function of an elastic solid. This replacement is effected by an integration by parts and neglecting the surface integral on the ground that at an indefinitely great distance the surface integral tends to zero, but this overlooks the fact that the law of variation of magnetic force with distance is not the same when the magnetic field is varying as it is when the magnetic field is steady. This does not affect Maxwell's investigation of the propagation of a magnetic disturbance, as this expression for the electrokinetic energy is not used in that investigation.

As has been seen, Faraday's view, as set forth in his 1845 paper, is different, and he explains his views in greater detail in a letter which was published in the *Philosophical Magazine* in 1846. In this letter he states:

The view which I am so bold as to put forth considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles and also masses of matter together. It endeavors to dismiss the aether, but not the vibration. The kind of vibration which, I believe, can alone account for the wonderful, varied, and beautiful phenomena of polarization, is not the same as that which occurs on the surface of disturbed water, or the waves of sound in gases or liquids, for the vibrations in these cases are direct, or to and from the centre of action, whereas the former are lateral. It seems to me, that the resultant of two or more lines of force is an apt condition for that action

which may be considered as equivalent to a *lateral* vibration; whereas a unifom medium like the aether does not appear apt, or more apt than air or water.

The occurrence of a change at one end of a line of force easily suggests a consequent change at the other. The propagation of light, and therefore probably of all radiant action, occupies *time;* and that a vibration of the line of force should account for the phenomena of radiation, it is necessary that such vibration should occupy time also.

And again:

The aether is assumed as pervading all bodies as well as space: in the view now set forth, it is the forces of the atomic centres which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is, that the aether presents successive parts or centres of action, and the present supposition only lines of action; as regards matter, the difference is, that the aether lies between the particles and so carries on the vibrations, whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued.

Faraday, like Fresnel, appears to be thinking in terms of geometrical relations, while Maxwell is seeking to construct a mechanical model whose motions will resemble those which constitute light.

Starting from Faraday's ideas, the problem of the propagation of a magnetic disturbance in free space can be approached in a direct manner. There are three vectors involved—the electric current at a point in the space, the magnetic force at the point, and the electric force at the point. The relation between the electric current and the magnetic force is given by Ampère's law,[4] and the relation between the magnetic force and the electric force is given by Faraday's law. Assuming, with Faraday, that the phenomena of light and of electricity have a common origin, Fresnel's law of transversality, that the vectors which specify the disturbance are perpendicular to the direction of propagation, will hold for the propagation of an electric or a magnetic disturbance as well as for light. These three laws are sufficient to determine the circumstances of the propagation of a magnetic disturbance in free space. It follows that for plane waves the direction of the vector j, whose time rate of increase is the electric current, at a point coincides with the direction of the electric force E at the point, and the relation between E and j is $E = 4\pi V^2 j$, where V is the velocity of propagation of a magnetic disturbance in free space. Further, if the changes which constitute the disturbance satisfy the laws of dynamics, the potential energy per unit of volume is $\frac{1}{2} Ej$—that is, $E^2/8\pi V^2$ in electromagnetic units—and, if E_1 is the same electric force in electrostatic units, the potential energy is $E_1^2/8\pi$; therefore $E = VE_1$, that is, the velocity of propagation is the velocity by which an electric force expressed in electrostatic units must be multiplied to convert it into electromagnetic units, or since the product of an electric charge and the electric force on it, being a mechanical force, is the same in both systems of units, the velocity of propagation is the velocity by which an electric charge expressed in electromagnetic units must be multiplied to convert it into electrostatic units.

The Lagrangian function of the changes which belong to the propagation of an electric or magnetic disturbance in free space is the difference of a kinetic energy function and a potential energy function. The potential energy function is the function given above—the kinetic energy function depends on the electromagnetic momentum and the electric current at a point; the contribution from an element in the neighborhood of a point can not be expressed in terms of one vector: it depends on the electric currents throughout space. On this theory the rate of transfer of energy from a source emitting waves of one frequency is steady and not oscillatory as on an elastic solid theory.

Consistently with the foregoing, the effect of material media, so far as electric and magnetic phenomena are concerned, can be represented by a distribution of electric currents and of magnetic currents throughout the space occupied by the material media. These electric current and magnetic current distributions can be supposed to be due to electric charges and to magnetic particles which are in motion, and it follows from the electrodynamical equations, when these current distributions are taken account of, that the current distributions can be represented by a distribution of electric and magnetic oscillators throughout the space occupied by the material media.

Further, the magnetic field due to a distribution of electric and magnetic currents inside a closed surface at any point outside this closed surface can be expressed in terms of the components of the electric and magnetic forces tangential to the surface—that is, any distribution of electric and magnetic currents inside a closed surface produces the same magnetic field at points outside the surface as a distribution of electric and magnetic currents on the surface which is determined by the components of the magnetic and electric forces tangential to the surface at points on it, but a knowledge of the magnetic field external to a closed surface does not determine the distribution of electric and magnetic currents inside the surface which is producing the magnetic field.

When the states of motion belonging to the electric and magnetic current distributions in the material

[4] It should be noted that Ampère's law was established initially for steady electric currents; its extension to the case where the electric currents are varying is a result of Faraday's work.

medium are steady states of motion the material medium is in a state of relative equilibrium, but, when an electric or magnetic disturbance is being propagated in the material medium, these steady states of motion will be disturbed and, under certain conditions, the effect of the disturbance will be to set up small oscillations about the steady states of motion; a material can be regarded as being perfectly transparent for a disturbance whose only effect is to set up small oscillations about the steady states of motion. A condition for this is that none of the frequencies involved in the disturbance are equal to or nearly equal to any of the natural frequencies belonging to the steady states of motion.

Fresnel's relations between the amplitudes of the incident, the transmitted and the reflected waves when a train of waves is incident on the surface separating two transparent media follow on this hypothesis, and also Fresnel's results for the propagation of waves in crystalline media. It should be noticed that on this hypothesis the electric and magnetic forces at a point in a material medium which appear in the equations are not the total electric and magnetic forces at the point, but the parts of them which are due to the disturbance.

Faraday's results for the rotation of the plane of polarization by an imposed magnetic field when light is being propagated in a non-magnetic transparent medium follow immediately from the above hypothesis without making any additional assumptions.

Further, on the same hypothesis there will be ranges of frequencies for which a material medium is transparent, the extent of such a range will depend on the intensity of the disturbances, and between any two consecutive ranges there will be a range of frequencies for which the medium is not transparent, and the mathematical treatment of the effect of disturbances involving these frequencies will require additional hypotheses.

The theory advanced above is not a mechanical theory of light in the sense that it is possible to construct a machine whose motions will resemble the motions involved in the propagation of light. The form of the electrokinetic energy function raises the question whether all the time rates of change involved in the propagation of a magnetic disturbance can be represented by moving points, and whether every time rate of change associated with physical phenomena involves change of position in space. It may be necessary to contemplate time rates of change which do not involve change of position in space, although they satisfy the laws of dynamics. In this connection it is of interest to observe that a result of Faraday's laws is that, when there are electric currents in a system of circuits which are in motion, the kinetic energy function does not contain terms which involve the product of an electric current and a velocity, a result which Maxwell verified experimentally.

A possible hypothesis is that physical phenomena are due to the interaction of time rates of change which satisfy the laws of dynamics, and the Lagrangian function in that case would be a homogeneous quadratic function of all the time rates of change. In actual cases only some of the changes are being observed, and the Lagrangian function which is obtained from the experimental evidence is a modified Lagrangian function where the unobserved changes are supposed to be eliminated. In certain cases this function will be expressed as the difference of a kinetic energy and a potential energy function; an important case is the case where the unobserved changes appear in the original Lagrangian function as velocities only and there are no product terms which involve a velocity belonging to the observed and a velocity belonging to the unobserved changes. There are also cases where the modified function is of this form approximately.

OBITUARY

WILLARD JAMES FISHER

DR. WILLARD JAMES FISHER, for the past twelve years research associate and lecturer in astronomy at the Harvard Observatory, died from heart failure on September 2. Dr. Fisher was born in Waterford, N. Y., in 1867. He was instructor in physics at Cornell University and professor at New Hampshire College and had been in charge of the departments of physics at the University of the Philippines and at the University of Hawaii. A correspondent writes: "Dr. Fisher's activity in recent years has been in the fields of lunar eclipse phenomena and meteoric astronomy. He has made many important contributions to knowledge of meteors, especially dealing with the phenomena of fireballs, meteoric dust, photographs of meteors and the distribution of iron and stony meteorites. A paper by him now in press calls attention to the significant fact that iron meteorites are found in America abundantly only south of the region formerly covered by the Pleistocene ice sheet; apparently the known iron meteorites are the gleanings of many geological periods, and most of those that fell in our northern states prior to the glacial ages have been buried below the agriculturally explored surface. Some years ago Dr. Fisher very successfully guided the organization of special lunar eclipse observers throughout the American Arctic, obtaining the assistance of the Canadian Mounted Police, the fu

traders, the missionaries to the Esquimaux and the Alaskan Signal Service of the United States Army; instructions were broadcast from the more powerful American radio stations."

MEMORIALS

A STATUE of Benjamin Franklin, believed to have been executed from life by the French sculptor, François Marie Suzanne, was presented to the Franklin Institute by A. Atwater Kent, president of the Benjamin Franklin Memorial, on July 16. The statue was discovered about fifteen years ago in an obscure shop in New York.

FUNDS are being solicited to establish a memorial in honor of the late Dr. Charles Spencer Williamson, professor of medicine at the University of Illinois College of Medicine. It is hoped to accumulate a fund of $500 for a suitable portrait of Dr. Williamson, to be hung in the library of the university, and a sum between $5,000 and $10,000 to establish a lectureship in internal medicine.

A MEMORIAL bronze plaque, in memory of Luther Marion Defoe, has been hung under his picture in the Engineering Library of the University of Missouri. This plaque, about 12 by 18 inches, was placed there by the members of the faculty of the College of Enginering. It bears the following inscription: "In memory of Luther Marion Defoe, A.B., 1860–1933. Professor of mechanics, University of Missouri, 1892–1933. Inspiring Teacher—Wise Counsellor—Just Judge."

A MONUMENT to John Lamont, the Scottish astronomer, who died in 1879, was unveiled at Inverary, his birthplace, on September 10, during the meeting at Aberdeen of the British Association for the Advancement of Science. Professor Lamont is known for his pioneer work in terrestrial magnetism. He was for many years director of the Royal Observatory at Munich.

RECENT DEATHS

DR. KARL FREDERIC KELLERMAN, associate chief of the Bureau of Plant Industry at the U. S. Department of Agriculture, died on August 30, at the age of fifty-four years.

HARRY CREIGHTON PEFFER, chemical engineer and founder of the School of Chemical Engineering at Purdue University, died from heart failure on July 17. Professor Peffer had been at Purdue since 1911, building up the School of Chemical Engineering to its present prominence. He also developed a number of research projects in chemical and industrial processes, building materials, etc.

DR. GEORGE C. BRANDENBURG, head of the department of education at Purdue University and director of its summer school, died on September 3. He was fifty-five years old. He is known for his work on child development and personality.

DR. MAURICE FISHBERG, specialist in tubercular disease, chief physician of Montefiore Hospital and Bedford Sanitarium, known for his work on the physical anthropology of the Jew, died suddenly on August 20. He was sixty-two years old.

DR. WILLIAM CAMPBELL POSEY, ophthalmologist, president of the College of Physicians, Philadelphia, died suddenly on September 6. He was sixty-eight years old.

CHARLES FREDERIC AUGUST SCHAEFFER, entomologist and for twenty-nine years until his retirement last March associate curator of coleoptera at the Brooklyn Museum, died on August 30. He was seventy-four years old.

WELLESLEY CURRAN CLINTON, professor of electrical engineering at University College, London, died on August 18 at the age of sixty-three years.

THE death is announced of Dr. William Mitchinson Hicks, emeritus professor of physics and first vice-chancellor of Sheffield University, at the age of eighty-three years.

PROFESSOR CARL OLAF JENSEN, director of the Danish Agricultural and Veterinary School, died on September 3, at the age of seventy years.

SCIENTIFIC EVENTS

COOPERATION AMONG LONDON MEDICAL SCHOOLS

PLANS are announced, according to an article in the London *Times*, for the closer cooperation for educational purposes of three medical schools in London in order to extend facilities for their students. Similarly, the London Voluntary Hospitals Committee and the Hospitals and Medical Services Committee of the London County Council have agreed upon plans for a greater degree of cooperation, one result of which is the linking up of twelve undergraduate teaching hospitals with a number of municipal hospitals.

The public importance of the decision of the governing bodies of St. Bartholomew's Hospital Medical College, St. Thomas's Hospital Medical School and Guy's Hospital Medical School to establish a closer cooperation for the advancement of medical education is emphasized in a statement issued by the deans of the college and schools concerned. They write:

The medical schools of London have grown rapidly during the past century and a half. They originated in a system of apprenticeship, under which the students became attached to individual members of the staffs of the various hospitals. Later this system was terminated and organized schools were established. Early in the present century these schools became constituent colleges of the University of London.

The range of medical education has now become so wide and the subjects included in the training of a doctor so complex that the problems of the teachers are becoming more and more difficult. It is to meet this difficulty that the cooperation between the three schools mentioned has come about. The first steps must necessarily be slow. An executive council has been formed, consisting of the dean and four other members of the teaching staff of each school. Meetings, at which subjects of educational importance will be discussed, will be held throughout the year. The decisions reached will be referred to each school for consideration and such action as may be agreed upon. In order that the cooperation may be as close as possible the dean of each school will be invited to attend the council meetings of the other two schools when subjects of general interest are being reviewed.

A further step has been taken. Certain courses of study are being organized for which it is difficult to cater in an individual school, but which can be arranged without difficulty when the students of more than one school will benefit. Further, the students of each school will be permitted, under an arranged scheme, to avail themselves of the clinical facilities of the other schools.

In order to allow the scheme to develop gradually, in some instances the arrangements for an interchange of clinical teaching will be restricted for an initial period to St. Bartholomew's and St. Thomas'. When, after some preliminary experience, the organization has become stabilized, similar facilities will be extended to students of Guy's.

It is hoped that cooperation on these lines will be of great value to the cause of medical education, and it is felt that the wider outlook thus made possible for the students must be of real benefit to them.

Conferences have recently taken place between representatives of the London Voluntary Hospitals Committee and the London Regional Committee of the British Hospitals Association with a view to the establishment, if possible, of a strong central committee to deal with the affairs of the London voluntary hospitals.

COOPERATIVE RESEARCH OF THE BUREAU OF FISHERIES AND THE UNIVERSITY OF MARYLAND

RECENTLY the Bureau of Fisheries and the University of Maryland inaugurated a program of cooperative research to develop the fisheries of the Chesapeake Bay region. The following is quoted from this cooperative working agreement endorsed by Frank T. Bell, Commissioner, U. S. Bureau of Fisheries, and Dr. R. A. Pearson, president of the University of Maryland:

Recognizing the need for scientific investigations of the fisheries and the various commercial products of the fisheries of the Chesapeake Bay area, it is hereby agreed that the University of Maryland and the U. S. Bureau of Fisheries, in the interests of the fishery industries of this region, to promote the general welfare of the consumer, and to contribute to the economic wealth of the Nation, will conduct, under the general supervision of the president of the University of Maryland and the Commissioner of the U. S. Bureau of Fisheries, such cooperative scientific research as may seem mutually advisable in accompanying the above purposes. It is expected that these studies will include chemical, nutritional, general technological and biological investigations of the fishery products of the area above-named. The initial study will be devoted to the products of the crab industry of this region.

Unless otherwise arranged in the case of one or two special projects, the general program of research will be under the joint direction of Dr. R. V. Truitt, biologist of the University of Maryland, and John Ruel Manning, chief technologist of the U. S. Bureau of Fisheries. Certain phases of the actual experimental or research work will be carried out both in the bureau's laboratories in Washington, D. C., and in the laboratories of the University of Maryland, College Park, Md., and will be conducted, as far as possible, with the personnel now available.

In signing this agreement, the Commissioner of the U. S. Bureau of Fisheries and the president of the University of Maryland believe that these cooperative investigations will promote the development of the fishery resources of the Chesapeake Bay area and will be of general economic benefit. We believe that the cost of these investigations will be much less by this cooperative arrangement than they would be if either organization undertook them alone and we believe that, by pooling and coordinating the administrative and technical training of our respective research staffs, better results can be obtained. In developing this program of cooperative effort, we trust that it will point the way to similar cooperative work between public institutions of this character.

There are already under way two research projects in this general program of cooperative research. The first of these is a study of the vitamin content and other nutritional properties of crab meat. The other project is an investigation of methods for canning crab meat.

CONSOLIDATION OF NATIONAL FORESTS IN ARIZONA

THE Kaibab and the Tusayan National Forests in northern Arizona are consolidated into one forest by an executive order signed by President Roosevelt on August 4, transferring most of the lands of the Tusayan to the Kaibab.

The consolidation will effect economies in administration, making it possible to handle the two units under a single administrative office. Supervisor Walter G. Mann, of the old Kaibab unit, with offices at Kanab, Utah, has moved to Williams, Arizona, where headquarters will be maintained for the enlarged Kaibab National Forest, which lies entirely within Arizona. Former Supervisor G. W. Kimball, of the Tusayan, has been transferred to the office of operations at the southwestern regional office of the Forest Service at Albuquerque, N. M. W. B. Dillon, administrative assistant of the Tusayan Forest, has been transferred to the Ouachita National Forest in Arkansas.

It is the intention of the Forest Service to attach to the Prescott National Forest the areas of the Tusayan unaffected by the Executive Order. A few thousand acres entirely under private ownership will be eliminated from the national forest boundaries.

The Kaibab National Forest is famous for its large herd of deer. From 3,000 in 1906, the deer increased under State and Forest Service protection to an estimated population in excess of 30,000 in 1924. The range began to show serious overgrazing, and starvation conditions prevailed. The Forest Service agreed to the removal of numbers of the deer to other forests and parks by trapping. Hunting was also liberalized. As a result of these measures the deer population has decreased somewhat, relieving the range from serious overgrazing. Under the Forest Service game management plans, the deer population will continue to be regulated to the capacity of the range.

The Tusayan Forest also contains many deer. It grazes in addition approximately 80,000 head of livestock annually. Both the Kaibab and the Tusayan Forest units consist largely of plateaus 7,000 to 9,000 feet high, and mountain peaks about 10,000 feet. There are almost pure stands of ponderosa pine. Besides deer, wild turkeys and other game live in these forests, and the Kaibab squirrel, a large species with white plumed tail, is found in the part north of the Grand Canyon, but nowhere else.

The new Kaibab National Forest will have a gross area of more than 1,000,000 acres. The north and south sections of it are now joined by good roads and bridges and by airline across the Grand Canyon of the Colorado River.

THE THIRD INTERNATIONAL STEAM TABLE CONFERENCE

THE third International Steam Table Conference will be held in Washington, Cambridge and New York from September 17 to 22. Invitations to the conference have been issued by The American Society of Mechanical Engineers in the name of its Special Research Committee on the Thermal Properties of Steam. The conference will provide an opportunity for research workers from abroad to inspect the experimental apparatus at the Massachusetts Institute of Technology and the Bureau of Standards, where work has been in progress since the formation of the special research committee in 1921, to review the results of research in the thermal properties of steam that have been obtained since the last conference, and to agree upon new and narrower tolerances for the values of the international skeleton tables on which the detailed published tables of Callendar in Great Britain, Hausen in Germany and Keenan in this country are based.

In this country, under the auspices of the American Society of Mechanical Engineers Special Research Committee on the Thermal Properties of Steam, experimental work has been in progress at Harvard University, Massachusetts Institute of Technology and the Bureau of Standards. At Harvard University, Dr. Harvey N. Davis and Robert V. Kleinschmidt have conducted a series of experiments on the Joule-Thomson effect. At the Massachusetts Institute, Dr. F. G. Keyes has set up apparatus for determining the pressure-volume relations, while at the Bureau of Standards Dr. Nathan S. Osborne has constructed a calorimeter in which measurements of heat content were made. A high degree of precision resulted from the carefully constructed apparatus and thoroughly scientific techniques employed in all these investigations. Dr. Davis's work was completed first, and from his data and under his supervision Joseph H. Keenan, then an engineer with the General Electric Company, undertook the computation of the values for a complete set of steam tables and Mollier (enthalpy-entropy) diagram. This work culminated in the Keenan "Steam Tables and Mollier Diagram" published in 1930 by The American Society of Mechanical Engineers.

Throughout these investigations, annual public meetings of the Special Research Committee on the Thermal Properties of Steam were held under the auspices of the American Society of Mechanical Engineers and the results were reported year by year in *Mechanical Engineering*. In July, 1929, the first International Steam Table Conference was held in London, with representatives from all the countries in which scientific work on the properties of steam were under way. Tangible results of the conference were the definition, for its own use, of the international kilowatt hour as being equal to 860 international kilocalories, and a skeleton table with tolerances to which all investigators agreed. At the second International Conference, held in Berlin, in June, 1930, the tolerances were narrowed as a result of the experimental work which had been done since the first conference. It is expected that the third conference, to be held this September, will result in even narrower tolerances.

The official delegates representing Great Britain at the conference will be G. S. Callendar and A. C. G. Egerton, of the University of Oxford, and H. L. Guy, chief engineer of the Mechanical Engineering Department of Metropolitan-Vickers Electrical Company, Manchester. The German delegates will be Professor Dr.-Ing. W. Hausen, Technische Hochschule, Munich; Professor Dr.-Ing. F. Henning, Physikalisch Technisch Reichsanstalt, Charlottenburg; Dr.-Ing. W. Koch, Technische Hochschule, Munich; Dr.-Ing. E. Michel, Swarthmore, Pa., and Professor Dr.-Ing. E. Schmidt, Technische Hochschule, Danzig-Langfuhr.

Geo. A. Orrok, of New York, is chairman of the committee in charge of the arrangements for the conference, and Alex Dow, president, Detroit Edison Company, is chairman of the American Society of Mechanical Engineers' Special Research Committee on the Thermal Properties of Steam.

VISITING ASTRONOMERS AT THE MOUNT WILSON OBSERVATORY

The Christian Science Monitor publishes a statement concerning astronomers from other observatories who have been working at the Mount Wilson Observatory of the Carnegie Institution during the present summer. As corrected for SCIENCE at the observatory this list reads:

Dr. Joel Stebbins, of the University of Wisconsin, with a photoelectric cell, observed stars in the region of the Milky Way to find whether their coloring is due to dust clouds in interstellar space.

Using a lens of his own design and the 10-inch telescope, Dr. F. E. Ross, of the Yerkes Observatory, University of Chicago, photographed the Milky Way in sections. Later he will piece his photographs together in a map.

Dr. Fred E. Wright, geophysicist of the Carnegie Institution, Washington, was engaged in making a globular photographic map of the moon.

Dr. John C. Duncan, of Wellesley College, photographed nebulae.

Dr. Samuel A. Mitchell, University of Virginia, observed the faint variable stars and compared them with the neighboring ordinary stars.

Dr. J. C. Boyce, the Massachusetts Institute of Technology, investigated elements known to be present in the sun and stars and searched for others.

Dr. Charles G. Abbot and L. B. Aldrich, of the Smithsonian Institution, made measurements of the sun's radiation and of the energy of some of the hotter stars.

Dr. Oliver J. Lee, Northwestern University, made observations of the spectra of stars.

Dr. C. M. Huffer, University of Wisconsin, made studies with the photoelectric cell.

Dr. and Mrs. Gaposchin, astronomers of Harvard University, studied the spectra of novae, stars which suddenly flare to great brilliance.

SCIENTIFIC NOTES AND NEWS

DR. ALBERT T. POFFENBERGER, professor of psychology and executive head of the department of psychology at Columbia University, was elected president of the American Psychological Association at the meeting held in New York from September 5 to 8. Dr. J. E. Anderson, of the University of Minnesota, and Dr. E. S. Robinson, of Yale University, were elected directors.

PROFESSOR EMIL ABDERHALDEN, director of the Physiological Institute of the University at Halle, has been elected a corresponding foreign member of the Vienna Academy of Sciences.

THE Guyot Prize for the best work in otology during the last five years has been awarded to Professor F. R. Nager, of Zurich, and to Professor Max Meyer, of Wurzburg.

THE new amphitheater of the New York State Fair has been named in honor of Henry Hiram Wing, for forty years professor of animal husbandry at Cornell University, in recognition of the distinguished service which he for many years gave to the dairy industry and the science of animal husbandry. At the ceremony of dedication, which took place on September 4, Owen D. Young made the presentation address and Dr. Frank P. Graves, president of the University of the State of New York, who was master of ceremonies, unveiled a bronze plaque commemorating the occasion. Professor Wing spoke in acknowledgment.

ASSOCIATE CURATOR PAUL C. STANDLEY, of the department of botany of the Field Museum, Chicago, has been invited to act as vice-president of the section for taxonomy and nomenclature of the sixth International Botanical Congress, to be held at Amsterdam in September, 1935.

FOR the fourth consecutive year, Dr. Henry L. Banzhaf, dean of the Marquette University Dental School, has been chosen president of the Dental Educational Council of America. Dr. Banzhaf is a past president of the American Dental Association.

THE Earl of Malmesbury has been elected president of the Health Congress of the Royal Sanitary Institute, which is to be held at Bournemouth, England, from July 15 to 20, 1935.

THE retirement is announced of Professor Horatio Scott Carslaw, for thirty-two years professor of pure and applied mathematics at the University of Sydney.

DR. VERNON C. DAVID, since 1929 clinical professor

of surgery, Rush Medical College, Chicago, has been appointed chairman of the department, succeeding Dr. Arthur Dean Bevan, who joined the faculty as professor of anatomy in 1888.

DR. FRED R. GRIFFITH, JR., professor of physiology at the University of Buffalo School of Medicine, has been appointed head of the department to succeed Dr. Frank A. Hartman, who recently resigned to become professor of physiology at the Ohio State University College of Medicine.

ROY W. CARLSON, research engineer of the University of California, has been appointed assistant professor at the Massachusetts Institute of Technology. Mr. Carlson, as head of the testing department of the Los Angeles County flood control district from 1927 to 1931, conducted research for materials in flood control structures.

SIR GEORGE NEWMAN, chief medical officer of the British Ministry of Health and of the British Board of Education, has been renominated as a member of the British General Medical Council for five years from October 9.

DR. GASTON RAMON, assistant director of the Institut Pasteur, has been nominated a member of the Superior Council of Public Health of France, in succession to the late Professor Calmette.

DR. E. P. PHILLIPS, of the National Herbarium, Pretoria, South Africa, under grants from the Carnegie Corporation and from certain South African organizations, is making a study of the botanical institutions of the United States.

DR. CHARLES BAEHNI, assistant at the Botanical Garden of Geneva, Switzerland, is now at the Field Museum of Natural History, Chicago, where he plans to spend a year in botanical research.

PROFESSOR Y. YAMAMOTO, of the Taihoku Imperial University, Taihoku, Formosa, is spending the summer months at the New York Botanical Garden studying specimens from the Augustine Henry collection of Formosan plants. This collection, made during the latter part of the nineteenth century, is the one on which the first enumeration of Formosan plants, published in 1896, was based.

THIS summer a number of teachers and advanced students have been working in the Yellowstone National Park on problems of geology, botany and zoology. These include: Arthur Howard, geology, New York University; Dr. John T. Rouse, geology, Hamilton College; Professor John W. Scott, zoology, University of Wyoming; Professor Aven Nelson, botany, University of Wyoming; Dr. C. W. Wilson, geology, Vanderbilt University; Dr. C. N. Fenner, geology, Carnegie Institution of Washington. This fall special studies on the trumpeter swan and Rocky Mountain bighorn will be undertaken by Dr. Harlow B. Mills and Wm. E. Kearns, of the Naturalist Department.

DR. L. W. HACKETT, assistant director of the International Health Division of the Rockefeller Foundation and at present engaged in malaria research in southern Europe, has been invited by the University of London to give the Heath Clark Lectures for the year 1934. The lectures will be given during the second week in December on the subject, "Malaria in Europe."

THE Harveian Oration will be delivered on October 18, before the Royal College of Physicians of London, by Dr. James Collier, whose subject will be "Inventions, and the Outlook in Neurology."

THE new research laboratories of Messrs. Eli Lilly and Company, Indianapolis, will be formally opened with appropriate ceremonies on October 11. Sir Henry Dale will deliver the main address at the afternoon session. Sir Frederick Banting and Dr. Irving Langmuir will also speak. At the dinner in the evening, addresses will be made by Sir Henry Dale, Dr. Elliott P. Joslin, Dr. George R. Minot, Dr. Frank R. Lillie, Dr. Charles R. Stockard, Dr. George H. Whipple, Dr. Carl Voegtlin and Dr. G. H. A. Clowes, director of the Research Laboratories.

THE fourth congress of the Latin Oto-rhino-laryngological Society will be held at Brussels from September 20 to 25 under the presidency of Dr. Edmond Buys, of the faculty of medicine and surgery at the University of Turin.

THE *Journal* of the American Medical Association reports that the ninth International Congress of the Far Eastern Association of Tropical Medicine will be held in Nanking, China, from October 1 to 7. This congress was originally set for October, 1933. Various sections will hold meetings on aspects of tropical disease, with special attention to cholera, leprosy, yellow fever, plague and malaria. The secretary of the congress is Dr. P. Z. King, Wei Sheng Shu, Nanking.

APPLICATIONS for the position of associate chemist (insecticides), Bureau of Entomology and Plant Quarantine, Department of Agriculture, must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than October 4. The entrance salary is $3,200 a year, subject to the usual deductions. Competitors will not be required to report for examination at any place, but will be rated on their education and experience.

THE South Carolina State Department of Health began a survey of hookworm in the state on September 1, under the direction of Dr. James A. Hayne,

state health officer, and Dr. Benjamin F. Wyman, Columbia, director of rural sanitation. Dr. Alvin E. Keller, professor of preventive medicine and public health, Vanderbilt University School of Medicine, will assist in the survey and corrective campaign. Every county in which the disease is prevalent will be visited and the results checked with a survey made by the Rockefeller Foundation in 1914.

SATURDAY afternoon lectures at the New York Botanical Garden for September, October and November will be held at 3:30 in the lecture hall of the museum building, the first beginning on September 8. The program follows: "Rambles in Hawaiian Mountains," Otto Degener, New York Botanical Garden; "Autumn Wild Flowers," Dr. John Hendley Barnhart, bibliographer and administrative assistant; "A Tour of the National Parks," Dr. Harold N. Moldenke, assistant curator; "Dahlias," Dr. Marshall A. Howe, assistant director; "Where Our Food Plants Come From," Dr. Elmer D. Merrill, director; "Autumn Coloration," Dr. A. B. Stout, director of the laboratories; "Bacteria in Relation to Diseases of Plants and Animals," Dr. F. D. Chester, New York Botanical Garden; "Australia," Dr. Forman T. McLean, supervisor of public education; "A Winter in Bermuda," Dr. Fred J. Seaver, curator; "Travels through Ontario," Dr. S. M. Pady, National Research Council fellow, New York Botanical Garden; "Plant Hunting in the Southern Appalachians," Mr. E. J. Alexander, assistant curator and curator of the local herbarium; "Hybridizing the Mold Fungi," Dr. B. O. Dodge, plant pathologist.

BY the will of the late John W. Hamilton, Mount Union College, Ohio, will ultimately receive $200,000 for establishing "the Jay Brown Hamilton School of All Sciences."

THE private chemical library of the late William Hoskins, chemist and inventor, has been acquired by the Museum of Science and Industry, Chicago. The data included in it are of a historical nature. The collection numbers several thousand items, including books, periodicals, pamphlets and slides. Dr. Hoskins made contributions to the development of resistance wire, now generally used in heating devices, as well as developments in chemical safety paper, luminous paints and chlorine recovery of gold.

A CORRESPONDENT of the London *Times* reports that a much needed extension of the department of chemistry at the University of Birmingham will be made possible by a gift of investments valued at £45,000 by Mr. Albert Edward Hills, a retired tube manufacturer. His intention in making the gift is to assist in the higher education of those who will be engaged in Midland industrial circles. A new chemistry block is to be erected, Mr. Hills making this stipulation because the existing premises are too cramped; a good deal of the present work is inconveniently carried on in huts. An increasing number of students is being trained in chemistry. In addition the post-graduate school provides facilities for thirty workers in research.

ACCORDING to *Museum News*, the Utah State Museum Association, Salt Lake City, has recently been organized to promote the establishment of a new state museum on the grounds of the capitol. A concrete building in the Mayan style is planned with two floors and mezzanine. The ground floor would cover a space 276 by 297 feet. The nucleus of these latter exhibits will be provided for by private collections, notably that of Charles N. Strevell, already offered to the museum.

ACCORDING to *Museum News*, Griffith Observatory, in Griffith Park, Los Angeles, with the third full-sized Zeiss planetarium to be erected in the United States, is nearly ready for opening to the public. The building, of reinforced concrete, contains the planetarium room with seating capacity of five hundred, provision for a 12-inch telescope and a coelostat, and space for exhibits of astronomy and other sciences such as geology, seismology, meteorology and oceanography. The main foyer of the entrance of the building is occupied by a Foucault free-swinging pendulum, which demonstrates the rotation of the earth by the change in its course. A gallery to the south of the entrance contains a model of a portion of the Moon's surface with a traveling light to produce the effect of sunlight on the face of the moon. Behind this gallery is the dome of the planetarium, 75 feet in diameter, sheathed in copper. On each side of the entrance, wings to the east and west provide space for the science exhibits and terminate in the two revolving domes, also copper covered, for the telescope on the east and the coelostat on the west. A seismograph and other scientific instruments are included in the plans for additional installations. The observatory has been constructed and equipped with funds bequeathed by Colonel Griffith J. Griffith. When it is complete and all exhibits installed it will be turned over by the trustee, the Security First National Trust and Savings Bank, to the City of Los Angeles and will be conducted by the Department of Parks.

THE London *Times* reports that the schooner *Penola* in which the British Graham Land Expedition is about to set out for the Antarctic, arrived recently in London, to be loaded with scientific apparatus and with provisions for three years. It was expected to sail on September 5. The *Penola* has been reconditioned and strengthened in readiness for the voyage. She will not sail with her full load, because the expedition's

aeroplane and a quantity of stores have already been sent out to the Falkland Islands. The expedition is setting out with the object of exploring territory between Luitpold Land and Charcot Land, and will fix its base on the west coast of South Graham Land, as far south as the ice permits.

DISCUSSION

REFORM IN THE SYSTEM OF SCIENTIFIC PUBLICATION

THE appearance of the letter from Dr. Atherton Seidell (SCIENCE, July 20, 1934, p. 70) on "Reforms in Chemical Publication," outlining the plan of Mr. Watson Davis for an improved method of recording and distributing the results of scientific research, prompts me to publish a résumé of a plan which I have discussed with several scientists during the past three years. Some of the points in the plan result from recent experiences with lithoprinting as a means of reproduction for text-book and other material. The following statement written a year ago sets forth some of the many reasons for a change in our system of publication and preservation, and briefly indicates another type of system which it appears would obviate most if not all of our present difficulties. It is to be noted that the plan suggested by Mr. Davis is similar in purpose to that outlined below and that the methods are only slightly different. It appears somewhat significant that independent approach to the problem has led at least two persons to virtually identical conclusions concerning the method of choice in the eventual solution of the problem.

The problem of providing means for the dissemination of scientific information has become more acute with the increase in the number of scientific investigators. It is becoming increasingly difficult for the journals which propose to publish the results of original research to function adequately. In America alone the number of persons who devote themselves so largely to scientific work as to require mention in Cattell's "American Men of Science" has increased fivefold from 1906 to 1933. To those acquainted with scientific work it is apparent that this increase in number of workers has resulted in at least a corresponding increase in the volume of scientific work needing publication.

The present "journal method" of publication had its origin in a local institutional, or even departmental, organ of publication. There was a character to a journal arising in a particular department given to it by its head, who was at once editor and chief contributor. The use of widely distributed periodicals for publishing scholarly work in full has appealed to the natural scientist apparently more than it has to philosophers and social scientists, who have long used the monograph system for their original contributions. It may be that scientists have been willing to condense their material and omit the majority of its detail in a way that other scholars have been unwilling or unable to do. It is a fact, however, that there arrives a point in the process of condensation and elimination beyond which one can not go without sacrificing the clarity and completeness of evidence.

It seems that this point has been reached in the requirements which editors of scientific journals are now forced to impose upon their contributors in order that the whole volume of results of current research may be reported in some manner.

The problem of scientific publication is becoming exceedingly acute from another angle, namely, that of the cost of providing working libraries in centers of scientific research. With the increase in volume of published material, the great majority of research libraries have been unable to keep up more than the pretense of maintaining complete files of all relevant periodicals. A survey of subscription lists in the United States shows that there are many periodicals in special fields for which there are only two or three subscriptions in the entire country. Even in the case of some of the most important periodicals in certain specializd fields, such as hematology, there are only ten subscriptions in the entire country. This condition is deplorable because it implies that a great many investigators must be without ready access to literature of primary importance to their own problems. It is, in all likelihood, a contributing factor to a lack of familiarity with important literature which is often evident in scientific papers. The notion that any reasonable number of libraries can at present hope to maintain a complete file of all relevant publications is a myth, which it seems should be dissipated as soon as possible.

The solution of the problem is of great importance, even if it is not simple. An increase in the number of periodicals or in the volume of those already in existence would accommodate the increased volume of publication, but it would do nothing to lighten the load on the libraries or on the investigator himself who finds it increasingly difficult to read the entire volume of original material in his own field.

There are three major objectives in any permanent solution of the publication problem. The first, and most important, is provision for full and adequate presentation of all aspects of the problem, including a reasonable historical introduction, a reproducible description of all methods of observation and a full presentation of experimental results and deductions.

The second objective consists in a device for adequate indexing and abstracting of all publications in order to lighten the burden upon the investigator who is finding the literature problem an overwhelming one. For many persons the difficulty in acquiring a working knowledge of what has already been done in the field is so great as to occupy his whole time to the exclusion of opportunity for original effort. There is no really sound reason why the duplication of effort in searching out all relevant material in the literature should be imposed upon every investigator in the field. I trust the time will never arrive when indexing and cataloging will be so perfect that an investigator will have to do no foraging on his own account; but there could be an enormous improvement in our existing workaday routine methods without danger of losing the opportunity for individual ingenuity in literary searches.

The third objective is to provide a mechanism whereby a library may, with a reasonable budget, maintain itself as an adequate working tool for investigators using it. Two changes seem to be indicated in order to bring about needed improvement in this line. The cost of publishing scientific material must be reduced. The expensive methods of printing and illustration must, it seems, give way to less expensive, yet entirely adequate, methods of reproduction. Scientific literature has a very limited distribution and the expense of type setting and engraving is not warranted, either from the point of view of the necessity for perfection and permanence, or from the economic angle. With the perfection of such methods as photolithography which lend themselves to the problem of inexpensive reproduction in limited editions, there seems no longer any necessity for the continuance of the time-honored methods.

Furthermore, the journal method itself is open to serious criticism as the most desirable means for publishing scientific results. A volume of a journal may contain anywhere from a single to two hundred separate and distinct publications. There are many so-called border line journals which contain infrequently very important contributions to investigators in a particular field. A working library can not afford to be without those contributions, neither can it afford to pay for the printing and distribution of all the irrelevant matter in order to provide itself with the small part which is really necessary. There are some journals whose entire content is useful in particular libraries. There seems to be no question but that a larger number of libraries could be completely stocked with substantially all relevant publications in particular fields if those publications were available as separata instead of being available only in connection with large quantities of irrelevant material.

In order to bring about these desired ends, it is suggested that an organization such as the National Academy of Sciences undertake the problem of supervising the publication of all scientific material in this country. Similar bodies might function in other countries. The academy would serve as a clearing house and depository for original documents. Once every two weeks a list of all titles, including a condensed abstract of each manuscript, would be sent to every contributing library, carefully and completely indexed as to the content of each paper. Each library would then indicate which papers it desired for its files in the form of separata. A lithoprinting would be made, the cost of each publication being determined by the number of requests received for it. The cost of reproduction would be low, and sale of copies after the first issue could probably be counted upon to provide most of the funds necessary for the abstracting and indexing service. It is estimated that several million dollars a year are spent for the purchase of strictly scientific periodicals in the United States. It is not hard to imagine a system whereby this project could be successfully handled with an expenditure considerably less than is necessary at present.

Difficulties arise in the fact that there would be handicaps during the establishment of any system so radically different from the existing one. A duplication of effort in attempting to keep two systems working would be uneconomical and prohibitive from that angle unless some endowed organization or governmental agency could undertake to carry such a project through the first few difficult years.

It is suggested that the American scientific societies consider these problems in their annual meetings, or appoint committees to work jointly in considering a general scheme.

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BIOLOGICAL VARIATION vs. ERRORS IN MEASUREMENT

MEASUREMENTS are made with instruments which differ greatly in precision. On the one hand, there are relatively accurate determinations, like weight and length. On the other, there are elusive estimates of color and quality, together with the difficult kinds of laboratory measurements typified by the settling method for estimating the sizes of particles in the soil. The investigator is under the unfortunate necessity of including the variation in his measurements with the variation of the entity measured. Frequently the former is trivial in comparison with the latter. However, in new experimental practises and new laboratory techniques the relative magnitudes of the

two kinds of variation may well be subjected to a critical test. If there are taken at least two independent observations on each individual, the method of analysis of variance[1] furnishes a convenient mode of testing the relation. Two examples are presented below.

Stark[2] investigated the relation between hardiness of apple varieties and the percentage of unfrozen water in shoots of one season's growth. The data were secured from fifteen varieties during each of eleven months. In each month the shoots from one variety were mixed and subjected to a temperature of -20° C. From the composite sample two determinations of unfrozen water were made by the heat-of-fusion method. How much of the observed variation may be attributed to the heat-of-fusion technique of measurement, and how much to the biological differences in the samples? The analysis of variance is as given in Table 1.

TABLE 1

Source of variation	Degrees of freedom	Mean square
Within composite samples	165	70
Between means of months	10	40,463
Between means of varieties	14	1,429
Month-variety interactions	140	203

It is assumed that the mean square for interactions is a valid estimate of experimental error.[3] If so, it may be further assumed that this mean square is the result of the addition of two estimates of variance: (i) that due to errors of measurement by the heat-of-fusion method, designated by V_M, and (ii) that associated with the biological variation in percentage of unfrozen water, V_B. The value of V_M is given directly by the mean square "within composite samples"; that is, $V_M = 70$. Hence,

$$2\ V_B + 70 = 203,$$

and therefore, $V_B = 66$. The conclusion is that the errors of measurement and the biological sources of variation in this experiment are almost equally represented in experimental error. So long as the former are so great, any increase of precision may well be sought in the improvement of the technique of measurement as well as in replication of the composite samples.

Smith and Brown[4] measured the percentage of carbon dioxide in the soil air at three positions in each of six 14 by 56 foot experimental plots on Carrington loam. At each position determinations were made in triplicate. The analysis of variance is shown in Table 2.

TABLE 2

Source of variation	Degrees of freedom	Mean square
Within positions	36	3.68
Between plot means	5	760.15
Between positions within plots	12	63.11

It may be assumed that the mean square "between positions within plots" is the sum of variances attributable to (i) errors in measuring the percentage of carbon dioxide in the soil air at each determination, $V_M = 3.68$; and (ii) variation in the concentration of carbon dioxide from one position to another in the plot, V_B. Then,

$$3\ V_B + 3.68 = 63.11,$$

from which, $V_B = 19.81$. This indicates a fairly satisfactory method of measurement. Increased precision in experiments of this kind lies in replication of the plots, accompanied by such experimental designs as will enable the investigator to separate from experimental error the natural variation among the plots.

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POLYEMBRYONY IN THE DOMESTIC FOWL

COMPLETE monovular twins and even triplets are occasionally found among chick embryos. Incomplete posterior or anterior duplications are more frequent. Quantitative data on the incidence of duplication appear to be lacking.

During the years 1929–1933, inclusive, a large number of incubated eggs of known history have been broken incident to hatchability studies at the U. S. Animal Husbandry Experiment Farm, Beltsville, Md. Eggs containing embryos which had died during the first week of development were broken on the seventh day of incubation. Those dying later and the hatched chicks were examined on the fourteenth day or at the close of the incubation period. All embryos which

[1] R. A. Fisher, "Statistical Methods for Research Workers," Oliver and Boyd, Edinburgh, 1932; George W. Snedecor, "Calculation and Interpretation of Analysis of Variance and Covariance," Collegiate Press, Inc., Ames, 1934.

[2] Arvil L. Stark, "Unfrozen Water in Apple Shoots as Related to their Winter Hardiness," a thesis submitted for the degree of doctor of philosophy, Iowa State College, 1934.

[3] George W. Snedecor, *loc. cit.*, pages 45–47.

[4] F. B. Smith and P. E. Brown, "The Concentration of Carbon Dioxide in the Soil Air under Various Crops and in Fallow Soils," *Iowa State College Journal of Science*, 8: 1–16, 1933.

had lived to the fourth day of incubation or longer were examined for possible duplication.

Two sets of complete, monovular twins, 27 anterior duplications and 63 posterior duplications were found among 64,716 Single Comb Rhode Island Red embryos and chicks examined. Among 57,646 embryos and chicks from various other breeds and crosses, there were one set of complete monovular twins, 12 anterior and 31 posterior duplications. Thus there was a total of 92, or 0.142 per cent. of duplication among Single Comb Rhode Island Reds but only 44, or 0.076 per cent. among the others. The probability that the difference between these two groups is due to chance is less than one in a hundred as judged by the X^2 test. Further, the incidence of duplication among the Rhode Island Reds was greater than that for the mixed group in each of the five years during which data were collected.

Stockard[1] attributed polyembryony in birds to interruption of development before the completion of gastrulation. Riddle[2] sought to test Stockard's hypothesis by retarding the development of prematurely laid (4 to 24 hours) eggs of pigeons and doves but was unable to produce duplications. The difference in incidence of duplication between the two groups of data presented in the present communication may indicate the presence of inherited factors influencing duplication among chick embryos. Obviously, the presence of such factors has not been demonstrated.

T. C. BYERLY
M. W. OLSEN

BUREAU OF ANIMAL INDUSTRY
U. S. DEPARTMENT OF AGRICULTURE

SOME NEW RECORDS OF OCCURRENCE OF NORTH AMERICAN FRESH-WATER SPONGES

So little is known of the distribution of fresh-water sponges on our western coast that it seems wise to make available all findings as a matter of record.

Through the kind cooperation of Dr. L. E. Griffin, of Reed College, Portland, Oregon, we have been enabled to examine two specimens from his collections. The first is a specimen of *Spongilla fragilis,* taken from a flume leading from a pond on the college campus. It was collected in October, 1929. The sponge is full of very abnormal spicules. The skeletal ones are smooth amphioxi, many of them bearing ball-like enlargements in the centers; other types of irregularities are also numerous. The gemmule spicules are extremely variable in size and are also often quite abnormal in structure, enlarged in the center or provided with angular projections. There are large numbers of small balls of silica, several times the diameter of the skeleton spicules, scattered through the sponge; some of them are regular smooth spheres, while others are distorted in shape and bear spines projecting at right angles to their surfaces—the spines vary a great deal in size and in number from one or two to many. The second specimen is *Spongilla lacustris,* collected by M. R. Clare in August, 1928, from Mud Lake, west of Bend, Oregon, in the Cascade Mountains, at an elevation of about 4,500 feet. The specimen bore no gemmules.

Dr. Trevor Kincaid has kindly given me bits of three specimens from his collection. Two specimens were collected from Lake Ozette in the extreme northwest corner of the state of Washington on May 29, 1932. One of these is *Spongilla lacustris,* with thin skeleton spicules, and the other is *Spongilla fragilis,* with very variable gemmule spicules. The third specimen from Dr. Kincaid was taken from the interior of a wooden pipe on the shore of Lake Washington, not far from the University of Washington, where Dr. Kincaid is head of the department of zoology. This specimen unfortunately does not bear any gemmules and can not be identified.

Dr. Jacques Rousseau and Dr. F. M. Victorin, of Quebec, Canada, have kindly sent me three more specimens of Canadian fresh-water sponges from new localities. One is a specimen of *Spongilla lacustris* from "Lac Jaune, near Quebec City, Province of Quebec, August 5th, 1931: collected by Br. Anselme." A second is also a *Spongilla lacustris,* collected by Dr. Victorin in "St. Theodore Co., Joliette, in Laurentides, North of Quebec, September 5th, 1931"; this sponge has somewhat heavier skeleton spicules than those of the first specimen. The third specimen is *Spongilla fragilis,* collected by Dr. F. M. Victorin and Jules Brunel in "Canal de Chambly, Conté Chambly, Province de Québec."

The writer has also collected some very small, young sponges from a lake in Seattle, Washington, in the fall of 1933, but since the skeleton spicules are regular smooth amphioxi and no gemmules are present, the sponge can not be finally identified. In the fall of 1932, the writer also collected *Spongilla fragilis* in very great abundance from a pond near Spring Valley, N. Y., where it was covering the stems of plants and the wall of a stone-lined runway with a thin coat over large areas. The pond had been drained and the sponge was very full of gemmules.

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SWARMING BEETLES

ON July 15, 1934, on the summit of Mount Pisgah, in North Carolina, I observed a swarming of Coc-

[1] C. R. Stockard, *Am. Jour. Anat.,* 28: 115–277, 1921.
[2] O. Riddle, *Am. Jour. Anat.,* 32: 199–252, 1923.

tinellid beetles which was unique in my experience. The summit of Pisgah—altitude 5,750 feet— is covered by a dense growth of laurel which was still in bloom. There is also a variety of other shrubbery and herbaceous vegetation, and no evident connection between the beetles and any special type of plant was noted. The day was comfortably warm—about 80°; the sky was about three fourths overcast by stratocumulus clouds and there was a gentle breeze. The hour was about noon.

At several points on the very summit the beetles occurred in masses on the ground and covering the stems of the bushes. They clung to each other in such a way as to completely cover the surface they were on and several layers in depth. For the most part they were quiescent but moved about actively when disturbed. They did not readily take flight. I have identified the species as *Hippodamia convergens.*

J. I. HAMAKER
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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A LOW TEMPERATURE SEMI-MICRO STILL

WHILE condensing some acetylated sugars, it was decided that the removal of one of the reagents (dihydroxyacetone monoacetate) could best be accomplished by distillation.

The thermo-fragility and high boiling point of this monoacetate (96° at 1 mm), as well as the small amount of the condensation product produced, demanded of the still certain characteristics which were embodied in the design shown in the figure.

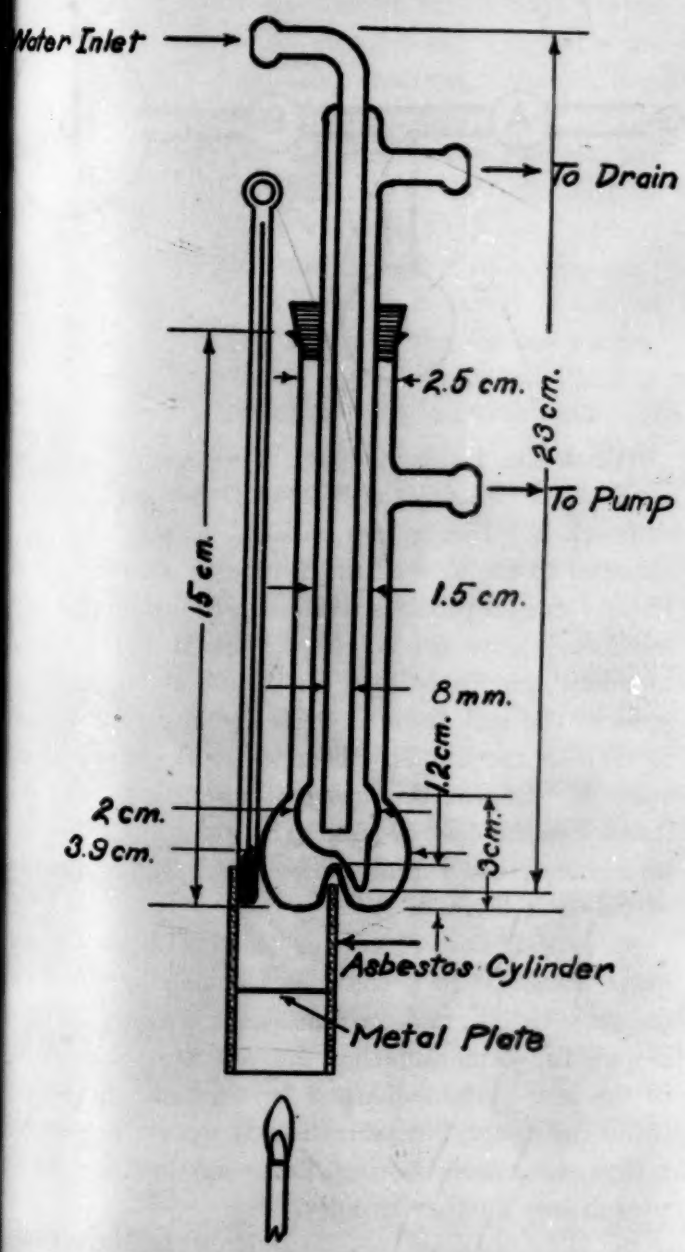

FIG. 1

The still consists essentially of a two-lobed glass flask. One lobe is for the material which is to be distilled, and the other is for the distillate. The vapors condense on the internal condenser, and the condensate drips off the teat into the receiving lobe.

When the still was used, the lobes were thermally separated by a thin strip of asbestos paper which encircled the distilling lobe and a thermometer bulb. A small metal plate was fastened in the center of this asbestos cylinder. An air-bath was constructed in this way, and the metal plate was heated by a micro burner. The receiving lobe was cooled by a wrapping of cloth wick which was kept moist by placing one end into a beaker of water. Cold water was run through the condenser. The distilling lobe was filled by the use of a pipette, and at the end of the distillation, the residue, which was a viscous liquid, was dissolved in water and removed by the use of a pipette.

An oil pump which produced a pressure of less than 1 mm was employed for distilling the monoacetate, and found to work well with a temperature difference of about 25° between the lobes.

If more involatile substances are encountered, the distillation may be facilitated by the use of a mercury or butyl phthalate pump backed by the oil pump, and a greater temperature difference attained by surrounding the receiving lobe with a freezing mixture held in a tin vessel bent to the proper shape. The condenser can be cooled better by circulating cold brine through it, or by vacuum-evaporating ether in it.

CHARLES L. BERNIER
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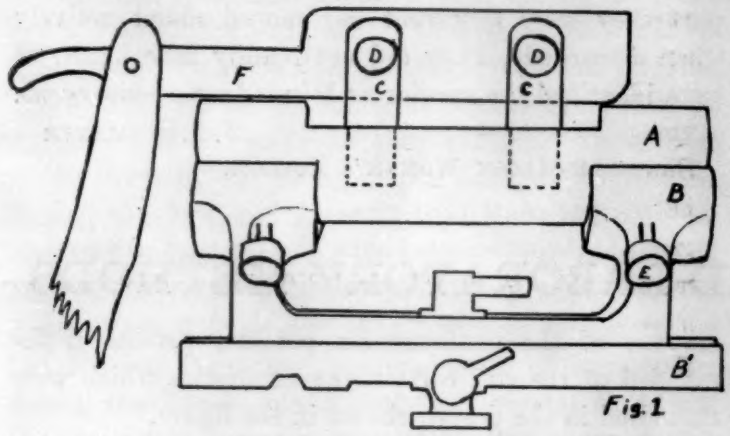
NEW TYPE RAZOR HOLDER FOR ROTARY MICROTOME

THE razor holder here described was designed for use on the Spencer rotary microtome. The ordinary heavy microtome knife has been objectionable because

of the time required and the difficulty of honing it properly for good paraffin sections. Safety razor blades have been used in various types of holders with only partial success. The razor (Fig. 1, F) has



FIGS. 1 and 2

been used by the author for more than two years with excellent success. It can be stripped and honed on a good quality slate hone in six to eight minutes, thus causing very little delay where a large number of preparations are to be turned out.

The razor holder (A), designed by the author and made by a student in the mechanical engineering department at a very nominal cost, replaces the microtome knife clamps in the base (B). It was made from 1¼ inch bar steel turned down to fit in the base (B), with sufficient play for electroplating. One side was leveled off to lower the height of the razor edge and give a base for the razor clamps (C). The clamps were made from flat steel $\frac{7}{8}'' \times \frac{1}{2}''$, one end turned down to $\frac{3}{8}''$, threaded and screwed into (A) $1\frac{1}{2}''$ apart. The opening in the clamp is $\frac{3}{8}''$ and just deep enough to keep the edge of the razor above the clamp (Fig. 1). Loosening the set screws (D) permits shifting of the razor, thus giving a maximum of cutting surface. Where a two-part base is used (B and B^1) the clamps could be spaced farther apart, making it easier to handle the ribbon and still secure the maximum cutting surface of the razor edge. A section of the bar (A) was cut out between the clamps as shown in the top view (Fig. 2) to allow the paraffin block to pass.

The type of razor and holder shown here is especially adapted for the investigator who has small material to work with and who wishes to get a large number of good sections in a limited time. Sections of fruit up to ¾ inch in diameter have been cut by the author. For larger sections the regular microtome knife would perhaps be more satisfactory.

This type of holder is also adapted for use in large classes in technique where each student is held responsible for the condition of his own razor.

G. F. GRAY

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A SIMPLE PUMP FOR INFLATING BALLOONS

THE science teacher occasionally needs a buoyant balloon for demonstration purposes, but he may find no apparent means at his disposal for securing it. The pressure in the gas mains is much too low to inflate a rubber balloon, and few laboratories are equipped with pressure tanks of hydrogen. The writer suggests the use of a second balloon to serve as pump for the balloon to be inflated. The only requirements are a T-tube, one or two stopcocks or pinchcocks, a little rubber tubing and patience.

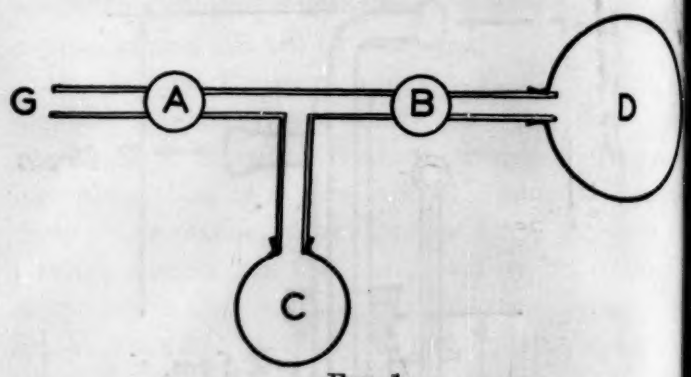

FIG. 1

Attach the T-tube through stopcock A to the gas main at G. Fasten the balloon D beyond the second stopcock B. The "pump balloon" C, similar to D, is attached to the arm of the T-tube by an elastic band. If only one stopcock is available, the gas-outlet valve itself may serve for A. Now, with B closed, open A to admit gas to balloon C. Close A, open B and squeeze the gas from C to D by applying pressure to C with the hands. Then close B, release C and open A. Repeat this cycle of operations until D is inflated to the desired size. This pumping action may be accomplished rapidly, once the rhythmic operation of valves is learned.

As is well known, two or three such floating balloons, fastened to a common mooring by threads of the same length, make a remarkably effective "electroscope" for demonstrating the presence of ionization in the air. When charged by friction, the balloons stand far apart, but ionization of the air produced by x-rays or a neighboring flame causes them to approach one another rapidly.

RICHARD M. SUTTON

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SPECIAL ARTICLES

MOSQUITO TRANSMISSION OF EQUINE ENCEPHALOMYELITIS

DURING the summer of 1933 the cases of equine encephalomyelitis in New Jersey, Delaware and Virginia were found only in areas close to salt marshes. If the disease is insect-borne, as the epidemiology and Kelser's[1] experiments with *Aëdes aegypti* indicate, the salt marsh mosquitoes must be considered as possible vectors. There are four species of mosquitoes in New Jersey that breed exclusively in salt marshes, *Aëdes sollicitans, Aëdes cantator, Aëdes taeniorhynchus* and *Culex salinarius.* Mosquito trap collection records[2] for New Jersey and Delaware show that, in the areas where the disease occurs and during the season of its greatest incidence, up to 90 per cent. of the specimens obtained are *Aëdes sollicitans. Aëdes cantator* occurs in considerable numbers early in the season but is relatively unimportant later. The other two species make up a small percentage of the total mosquito population throughout the season. Two other species of mosquitoes, *Anopheles quadrimaculatus* and *Anopheles crucians,* although breeding on the salt marshes, have a much wider distribution and, therefore, like the fresh water species, are unlikely vectors of a disease which is confined to salt marsh areas. *Aëdes aegypti,* as Kelser points out, can not be the transmitting agent of either the western or eastern disease, as it is rarely found as far north as the region in which the disease occurs.

In repeated tests we have demonstrated that *Aëdes sollicitans* will transmit both eastern and western strains of equine encephalomyelitis. For these experiments we have secured large numbers of these mosquitoes in the larval and pupal stages from salt marshes and have allowed them to emerge as adults in the laboratory. Insects receiving as an infective meal a mixture of guinea pig brain virus suspension and normal horse blood have not transmitted the disease to guinea pigs when allowed to feed on them 2, 3 or 4 days after the infective meal. Transmission has been consistently obtained on the seventh day and thereafter. *Aëdes sollicitans* has transmitted the eastern disease from infected to normal guinea pigs 11 days after the initial feeding and at later periods. When these mosquitoes fed on an infected horse the first transmission occurred after 20 days, there having been no transmission at 14 days. Twelve other mosquitoes of this lot, which were allowed to feed upon a normal horse at the 30-day period, failed to infect it. Seven of these same mosquitoes transmitted the disease to a guinea pig 3 days later. Although this one attempt to obtain horse to horse transmission was negative, we believe that the evidence is sufficient to establish *Aëdes sollicitans* as a probable vector of equine encephalomyelitis in the eastern states.

Aëdes sollicitans has also transmitted the western virus after engorging on brain virus suspension. Since, however, it is a salt marsh mosquito it can not be the vector of the disease in the west, and we suggest that a different vector or means of transmission may explain the serological difference which we[3] have shown exists between the viruses from the two regions.

Of the remaining salt marsh mosquitoes the few tests made with *Aëdes cantator* indicate that it will transmit eastern virus but less readily than *Aëdes sollicitans. Aëdes taeniorhynchus* is now being tested, while *Culex salinarius* has not been secured in sufficient numbers for test. The more widely distributed mosquitoes, *Culex pipiens* and *Anopheles quadrimaculatus,* have uniformly failed to transmit either the eastern or western strains of virus.

In parallel experiments in which the mosquitoes have been allowed to feed on brain virus suspension we have consistently obtained transmission of western but not of eastern virus by *Aëdes aegypti.* In occasional instances, however, this mosquito has transmitted eastern virus from infected to normal guinea pigs, whereas in parallel experiments with western virus transmission has been uniformly obtained.

Our experiments show that when either *Aëdes aegypti* or *Aëdes sollicitans* are fed on guinea pigs with a low virus content in their blood, the virus is soon lost and the mosquitoes do not transmit the disease. In order to act as vectors mosquitoes must be fed on infected animals at a time when the virus content of the blood is such that 0.0001 cc or less will produce the disease when it is injected into a guinea pig. Such a blood titer appears in general to be reached at the height of the first febrile reaction and before any central nervous system symptoms become manifest. It is not clear why this high virus content of the infective meal is necessary, since titration experiments with ground suspensions of mosquitoes indicate that there is an increase of virus in the mosquito. In both *Aëdes aegypti* infected with western virus and *Aëdes sollicitans* infected with the eastern virus a 1,000 to 10,000 fold increase of the virus within the mosquitoes has been demonstrated.

Whenever possible, at least twenty mosquitoes have been used in all transmission tests. In several instances, however, from four to seven *Aëdes sollicitans*

[1] R. A. Kelser, *Jour. Am. Vet. Med. Assn.,* 82 (n.s. 35): 767, 1933.

[2] T. J. Headlee, *Proc. 20th Ann. Meet. N. J. Mosquito Extermination Assn.*: 33, 1933; L. A. Stearns, D. MacCreary and N. P. Newhouse, *Del. Agric. Exp. Sta. Bul. 181,* 1933.

[3] C. Ten Broeck and M. H. Merrill, *Proc. Soc. Exp. Biol. and Med.,* 31: 217, 1933.

have transmitted the eastern disease to guinea pigs, and in one instance the bite of one *Aëdes aegypti* transmitted the western virus to a guinea pig. Three other insects of the same lot, each fed upon a different animal, failed to infect. The virus appears to persist in at least some of the mosquitoes as long as they live. Eastern virus has been transmitted by *Aëdes sollicitans* 33 days after the infective meal, the longest period we have been able to keep a sufficient number alive for test. The longest period we have found *Aëdes aegypti* capable of transmitting the western disease is 63 days. Virus was shown to be present in this same lot of mosquitoes 93 days after feeding, but they did not transmit the disease at this time.

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MECHANISMS IN THE DEVELOPMENT OF AN ACTIVE RESISTANCE TO THE EFFECTS OF SUBSTANCES STIMULATING THE THYROID GLAND IN THE GUINEA PIG

IF by means of extirpation of considerable portions of the thyroid, growth processes leading to compensatory hypertrophy are initiated in the guinea pig, simultaneous administration of KI intensifies these proliferative changes.[1] Similarly, if KI is either given orally to or injected intraperitoneally in certain quantities into guinea pigs or rats with normal thyroids, a marked increase in mitotic proliferation as well as a slight increase in the size of the acinus cells of the thyroid and a moderate softening of the colloid, accompanied by the invasion of this latter substance by phagocytes, can be observed.[2] These changes reach a maximum within a certain time, which varies according to the mode of administration of the iodine salt and differs in guinea pig and rat. When injections are continued following this period of maximum effect, a decrease in the mitotic activity occurs; the gland returns to the normal or perhaps to a subnormal level of activity; at the same time the acini may become distended with colloid.

Corresponding observations can be made, if instead of iodine salts we inject optimal quantities of extracts of anterior pituitary glands of cattle into guinea pigs; however, in this case the effects are much greater. There is an extraordinary increase in mitotic proliferation of the thyroid; the acinus cells increase very much in size and the colloid is largely liquefied and absorbed; thus the whole gland changes its structure and becomes similar to the thyroids seen in very pronounced cases of Graves' disease.[3] Furthermore, it is possible by these means to imitate the principal functional symptoms of this disease. But in this case also, after a stage of the maximum effects has been reached, a return of the thyroid gland to its normal state may take place gradually, notwithstanding the continued injections of the extract;[4] in a parallel way a decrease in the functional and metabolic hyperactivity of the gland sets in.[5] Similar observations were recently recorded by Collip and Anderson in the rat[6] and by Hertz and Kranes in the rabbit.[7]

As to the mechanism underlying this process of retrogression, we tested about three years ago the ability of the blood serum of guinea pigs, which had become resistant to the effects of anterior pituitary extracts, to neutralize these extracts *in vitro;* we made mixtures of such blood serums and extract and injected them into fresh guinea pigs. In control experiments we injected mixtures of normal guinea pig serum with anterior pituitary extracts. The results of these experiments were negative (see footnote 3-c). However, in their recent experiments, Collip and Anderson succeeded in demonstrating that the serum of rats which had become refractory to extracts was able not only to prevent the rise in metabolism otherwise caused by the injection of the thyroid stimulating hormone of anterior pituitary, if serum and extract were mixed *in vitro* previous to injection, but even to lower the basal metabolic rate of the injected animal.[8] We may therefore conclude that the development of substances neutralizing the thyroid stimulating hormone of the anterior pituitary gland and circulating in the blood of the injected animals is one of the mechanisms underlying the acquired resistance to the effects of the extract.

But we believe that there are reasons for assuming

[1] Leo Loeb, *Jour. Med. Research,* 40: 199, 1919, 41: 481, 1920; *Am. Jour. Path.,* 2: 19, 1926; 5: 71 and 79, 1929. S. H. Gray, *Am. Jour. Path.,* 5: 415, 1929. Elizabeth Moore, *Archives of Path.,* 16: 657, 1933.

[2] (a) S. H. Gray and Leo Loeb, *Am. Jour. Path.,* 4: 257; (b) I. Rabinovitch, *Am. Jour. Path.,* 4: 601, 1928; 5: 91, 1929; (c) *Proc. Soc. Exp. Biol. and Med.,* 28: 394, 1931.

[3] (a) Leo Loeb and R. B. Bassett, *Proc. Soc. Exp. Biol. and Med.,* 26: 860, 1929; (b) 27: 490, 1930; (c) Leo Loeb, *Klin. Wochensch.,* No. 51 and 52/53, pp. 2121 and 2156, 1932.

[4] Leo Loeb and Hilda Friedman, *Proc. Soc. Exp. Biol. and Med.,* 29: 172, 1931; Leo Loeb, *Klin. Wochensch.,* Nos. 51 and 52/53, pp. 2121 and 2156, 1932.

[5] (a) W. J. Siebert and R. S. Smith, *Proc. Soc. Exp. Biol. and Med.,* 27: 622, 1930; *Am. Jour. Physiol.,* 93: 396, 1930; (b) W. J. Siebert and E. W. Thurston, *Proc. Soc. Exp. Biol. and Med.,* 29: 652, 1932.

[6] M. B. Collip and E. M. Anderson, *Lancet,* 226: 76, 1934.

[7] S. Hertz and A. Kranes, *Endocrinology,* 18: 415, 1934.

[8] M. B. Collip and E. M. Anderson, *loc. cit.*

that in addition to this mechanism also other mechanisms may play a rôle in this process of immunity. The following facts seem to us to favor such a conclusion. (1) The curve representing the rise and fall in the mitotic proliferation in the guinea pig thyroid glands shows a maximum in the first few days of the injections and then declines at a time when neutralizing substances can not yet have developed (see footnote 3-a). (2) The curves representing the first stage of increasing stimulation and the following stage of decline are in principle similar in the case of the anterior pituitary hormone and of iodine preparations acting as stimulants. It appears improbable that the acquired resistance to the effects of iodine is due to the development of iodine-neutralizing substances, able to act *in vitro*. Moreover, in the rat the maximum stimulation is reached as early as five days following the beginning of the injections and then a rapid decline sets in, at a time therefore too early for the development of neutralizing substances (see footnote 2-c). (3) There is known already a mechanism counteracting the thyroid stimulating effect of anterior pituitary hormone and initiated through the injection of anterior pituitary extract which is not dependent on the action of substances neutralizing the hormone *in vitro*. It consists in an increase in the production of thyroid hormone. The latter tends to lower the level of reactivity of the thyroid gland to all stimuli so far tested, such as the removal of a great portion of the thyroid gland,[9] administration of KI[10] and injection of anterior pituitary extract.[11] (4) There is reason for assuming that the neutralizing substances develop in response to the injection of a protein from which the thyroid stimulating hormone of cattle anterior pituitary could not be separated so far; this protein is foreign to rat or guinea pig. We may tentatively assume that a less complex chemical group attached to this protein functions as the hormone proper. An excess of the animal's own thyroid stimulating hormone would therefore not lead to the production of a hormone-neutralizing substance, although it may activate other antagonistic mechanisms, such as the one mentioned under No. 3. (5) In the case of mouse tumors it has been possible to show that the relative immunity, which develops against the action of substances inhibiting tumor growth, such as colloidal metals and hirudin, depends upon a combination of two processes, one residing in the organism and a second one developing in the affected tumor cells themselves.[12] It is probable that we have to deal with a similar combination of mechanisms also in the case of the thyroid-stimulating hormone of the anterior pituitary. We may assume that the change which takes place in the stimulated acinus cells of the thyroid gland alters their response to the subsequent application of the same kind of stimuli. The intensity of reaction must necessarily decrease in the course of continued application of stimuli; otherwise the results of stimulation would accumulate in geometric progression.

Retrogressive changes during long-continued injections of anterior pituitary extracts are not limited to the thyroid gland; the changes produced in the ovary of the guinea pig also disappear and at about the same time as those in the thyroid. In this connection it may be stated that in experiments with Hilda Friedman, we have found it impossible so far to separate the stimulating effect of the anterior pituitary on the thyroid from the effects of this substance on the ovary of the guinea pig. The latter consist in atresia of the follicles, in the formation of interstitial gland and of pseudocorpora lutea of theca interna origin (see footnote 3-b). The term "thyrotropic" hormone does not therefore seem suitable for a substance which invariably also exerts "gonadotropic" functions. The term "thyroid stimulating" characterizes this hormone sufficiently without implying that it is specifically "thyrotropic."

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[9] Leo Loeb, *Jour. Med. Res.*, 41: 481, 1920.

[10] S. H. Gray and I. Rabinovitch, *Am. Jour. Path.*, 5: 485, 1929.

[11] Leo Loeb, R. B. Bassett and Hilda Friedman, *Proc. Soc. Exp. Biol. and Med.*, 28: 209, 1930.

[12] M. S. Fleisher, Miguel Vera and Leo Loeb, *Jour. Exp. Med.*, 20: 522, 1914; M. S. Fleisher and Leo Loeb, *Jour. Exp. Med.*, 21: 155, 1915.

RETENTION OF CARBON DIOXIDE GAS IN THE INTERCELLULAR ATMOSPHERE OF PEARS AND APPLES

THE use of carbon dioxide other than as a refrigerant offers many possibilities in the field of horticultural science. The recent work of Brooks *et al.*[1] has indicated its value in preventing fungal infection and in the retardation of the respiratory processes during transportation of perishable fruit and vegetables. Kidd and West[2] have shown that in the gas storage of apples under certain controlled conditions carbon dioxide markedly increased the storage life of the fruit. Results obtained by Harley and Fisher[3]

[1] C. Brooks, E. V. Miller, C. O. Bratley, J. S. Cooley, P. V. Mook and H. B. Johnson, "Effect of Solid and Gaseous Carbon Dioxide upon Transit Diseases of Certain Fruits and Vegetables," *Tech. Bul.* 318, U. S. Dept. Agr., 1932.

[2] F. Kidd and C. West, "Gas Storage of Fruit. III. Lane's Prince Albert Apples," *Jour. Pomol. and Hort. Sci.*, 11: 149, 1933.

[3] C. P. Harley and D. F. Fisher, "A Study of the Internal Atmospheres of Apples in Relation to Soft Scald," *Proc. Amer. Soc. Hort. Sci.*, 271, 1930.

and by Brooks and Harley[4] have indicated that control of soft scald might be obtained by subjection of the fruit to an atmosphere of carbon dioxide prior to storage at low temperature.

Some work was undertaken during the current season in comparing the effectiveness of carbon dioxide treatment with that of precooling in the retardation of the ripening processes of fruit prior to storage at 32° F. A question arose as to the concentration of the gas in the intercellular atmospheres immediately following treatment and also as to the retentive capacity of various tissues for this gas. This short communication is a partial answer to some of these questions.

EXPERIMENTAL

Packed boxes of Bosc pears and Jonathan apples were placed in a suitable container immediately following harvest and treated with 35 per cent. carbon dioxide for 24 hours at 65° F. A representative number of untreated fruits were immediately sampled, and an analysis made of the gases in the intercellular spaces of the tissues. The gases were withdrawn from the tissues by a modification of the apparatus described by Magness[5] and analyzed in a Bonnier-Mangin gas analysis apparatus.

This sampling procedure was repeated on the gas-treated fruit immediately following and at stated intervals after the fruit had been removed to the ordinary atmosphere. Data and results are summarized in Fig. 1.

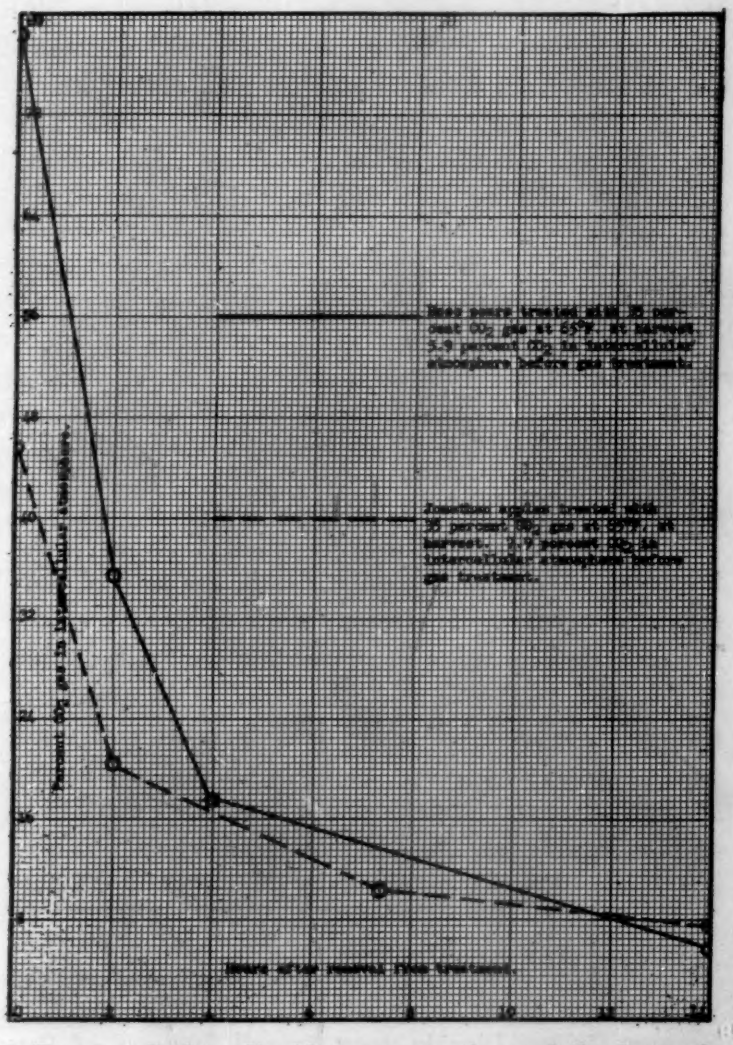

FIG. 1. Carbon dioxide concentrations of the intercellular atmospheres at definite periods following removal of the fruit from treatment with 35 per cent. CO_2 for 24 hours at 65° F. Wenatchee, Wash. 1933.

It is interesting to note that carbon dioxide is absorbed to a much greater extent in Bosc pear than in Jonathan apple tissues. In an atmosphere of 35 per cent. of this gas, apples had an intercellular carbon dioxide concentration of nearly 50 per cent. and pears 80 per cent. at the end of the gas treatment. Fig. 1 offers a graphic picture of the speed with which this excess carbon dioxide gas is removed from the intercellular spaces. Approximately 70 per cent. of the accumulated carbon dioxide in the tissues has been lost within eight hours after removal from the gas treatment. The carbon dioxide concentration of the intercellular atmospheres of both the pear and apple show a normal value within 14 hours after removal from gas treatment.

The fact that fruits of this kind have such a short retentive capacity for carbon dioxide must be considered in problems of precooling as well as in those involving respiratory changes. The supposition is suggested that fruit responses to non-lethal carbon dioxide gas treatments are confined largely to the actual period while under such treatment. Respiration and ripening data at hand bear out this suggestion.

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BOYCE D. EZELL

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[4] C. Brooks and C. P. Harley, "Studies on Soft Scald and Soggy Breakdown of Apples." Submitted for publication in *Jour. Agr. Research*. 1934.

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